AD-A153 404

INSTITUTE REPORT NO. 196

PURSUIT TRACKING PERFORMANCE AND FLASH DISRUPTION: THE EFFECTS OF TRAINING THE NON-DOMINANT EYE ON TARGET REACQUISITION

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FEBRUARY 1985

LETTERMAN ARMY INSTITUTE OF RESEARCH
PRESIDIO OF SAN FRANCISCO, CALIFORNIA 94129

Pursuit tracking performance and flash disruption: The effects of training the non-dominant eye on target reacquisition--Molchany et al.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Institute Report No. 196 — 2. GOVT ACCESSION NO. AD-A153 404	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Pursuit Tracking Performance and Flash Disruption: The Effects of Training the Non-Dominant Eye on Target Reacquisition	5. TYPE OF REPORT & PERIOD COVERED Final - March-July 1984 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jerome W. Molchany, BS, SP5(P) USA; David A. Stamper, MA; and Richard R. Levine, Ph.D., CPT(P) MSC	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Letterman Army Institute of Research Division of Ocular Hazards Presidio of San Francisco, CA 94129	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project No. 3E162777A878 WU 161 Laser Technology
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research & Development Command Fort Detrick Frederick, MD 21701	12. REPORT DATE February 1985 13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

This document has been approved for public release and sale; its distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Pursuit Tracking, Flash Disruption, Dominant Eye. Non-dominant Eye Humand Volunteers, Target Reacquisition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Shifting from the sighting to the non-sighting eye represents a possible solution for operators of monocular viewing devices (e.g. TOW, GLLD) whose vision is temporarily disrupted from the effects of flash. Twenty-four male volunteers used a viscous-damped mount optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and dim ambient light conditions. Pursuit tracking data were collected under simulated field conditions (BLASER). Volunteers were randomly assigned to one of the three groups. The first group received no training of the non-sighting eye. The second group

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ABSTRACT

Shifting from the sighting to the non-sighting eye represents a possible solution for operators of monocular viewing devices (e.g. TOW, GLLD) whose vision is temporarily disrupted from the effects of flash. Twenty-four male volunteers used a viscous-damped mount optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and dim ambient light conditions. Pursuit tracking data were collected under simulated field conditions (BLASER). Volunteers were randomly assigned to one of the three groups. The first group received no training of the non-sighting eye. The second group received training with both the sighting and non-sighting eyes, individually. The third group was trained in the same manner as the second group, except that they were also trained to switch eyes during tracking trials. Each group received 4 training days and one test day. On the test day, a monocular full-field flash was used. The volunteers were instructed to switch eyes and reacquire the target with the non-sighting eye to complete the task. Analysis of Variance (ANOVA) for horizontal RMS error scores revealed no significant group main effect for either the sighting eye baseline or the non-sighting eye baseline. The maximum absolute error (MAE) scores for Group 3 under both bright and dim ambient light conditions were significantly better than Groups 1 and 2. It was concluded that training monocular devices operators to switch from the sighting eye to the non-sighting eye following disruption of pursuit tracking represents a temporary solution to the debilitating effects of flash blindness.

PREFACE

We express our thanks to SP4 Daniel Cheng and SP5 Helen Ford for their technical support during the data collection phase of this project. We would also like to thank Mr. David J. Lund for the measurements of the ambient light levels and flash qualities, and COL Edwin S. Beatrice, MC, for his support during the conduct of this project and preparation of this manuscript. We are indebted to Virginia Gildengorin, PhD, for her invaluable assistance with the statistical evaluation of the data and Lottie B. Applewhite for her expert editorial improvements.

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Within the current military arsenal are many weapon systems requiring the operator to acquire, designate and track moving targets by using a monocular optical device. The eye selected for a monocular sighting task may be defined as the sighting-dominant eye (1).

If a soldier using direct view optics experienced a temporary loss of visual function in the sighting eye, he might be unable to complete his mission. Impairment of visual function could result from exposure to many hazards on the battlefield. Pyrotechnics, high-intensity searchlights, electronic strobes, and the flash from a nuclear fireball represent some of the ocular hazards associated with the battlefield scenario. Potential exposure to directed energy from laser systems operated by enemy forces adds another threat to our combat troops. Within this scenario, the operator of such devices as laser designators and optically-sighted, wire-guided missiles may receive a brief, intense laser exposure from active threat devices. Flash blindness or ocular damage can result. Both can produce serious decrements in performance. The magnifying optics in such devices dynamically increase the potential for ocular insult (2).

The mechanisms underlying ocular dominance are not completely understood (3,4). Sighting-dominant eyes exhibit better visual acuity (5), image clarity (6), color perception (7) and a faster visual processing time (8) than non-dominant eyes. Also, with the sighting-dominant eye, images may be perceived as being larger (5). This implies that vision with the non-dominant eye has neither the accuracy nor clarity of the sighting-dominant eye.

Current military doctrine does not emphasize the cross-training of eyes for pursuit tracking tasks. An operator who has been exposed to a bright flash of light therefore could be eliminated as an effective member of the fighting force. Shifting from the sighting (dominant) eye to the non-sighting (non-dominant) eye may represent a possible solution for the temporarily debilitating effects of flash exposure. However, these tasks require extreme accuracy and to switch eyes during a firing mission without training could result in mission failure. Thus, we need to know the effects of training on the reacquisition of targets if a soldier had to change eyes while tracking. This study was designed to evaluate specific paradigms for training the non-dominant eye for target reacquisition following flash disruption of pursuit tracking with the sighting-dominant eye.

METHODS

Volunteers. Twenty-four experimentally naive enlisted men, (ages 18 to 35; mean age 24.6 yrs), from the 7th Infantry Division, Ft. Ord, California, served as participants. Each volunteer was administered a series of visual function tests to eliminate those soldiers with visual deficits. The tests included a battery of ocular dominance tests, the Snellen Visual Acuity Test, and the Ishihara Test for Color Blindness (Kanchase Shuppan Co., Tokyo, Japan 1969). Ocular dominance was determined by the Box test, Card test and Pointing test from Coren (3) and Crider (9). These tests are described in detail in Appendix Only volunteers with 20/20 visual acuity (both eyes), corrected or uncorrected, normal color vision, and judged to be right-eye, right-hand dominant were accepted as participants for this study. Of the 27 men tested, one was excluded by the visual function tests results and two did not meet the right-eye, right-hand dominance criteria.

Apparatus. Pursuit tracking performance was evaluated in the BLASER tracking simulator. The simulator consisted of a scale model T-62 Russian tank target on a terrain board and a full-sized sandbag bunker which housed the viscous-damped optical tracking device. The tank was track-mounted and driven across the terrain in 2 directions (left-to-right, right-to-left). The tank traversed an arc located approximately 5 m from the operator. The unity power optics located in the tracking device simulated a distance of 1 km. The target traveled across the terrain for 15 sec at a constant angular velocity of 5 mrad/sec. A 0.46-mrad square aiming patch was affixed to one side of the tank in a center-of-mass position. An infrared light-emitting diode (IR LED), located in the center of the aiming patch, was imaged by a television camera mounted coaxially with the optics of the tracking device. The IR LED was invisible to the operator. Its signal provided a reference source for the microprocessor and associated software to monitor performance electronically.

The flash source was a Vivitar 125 photoflash unit with a green Kodak Wratten filter (No.58). An aperture was attached to the photoflash unit to produce an 11° retinal image. The flash duration was 115 μs and the radiance was 0.06 $J/cm^2 sr$. A flash of this magnitude elicited a startle response that induced the operator to pull his head away from the eyepiece of the device. The maximum irradiance was one-eighth of the maximum permissible exposure (MPE) given in TB MED 279 (10).

Tracking performance data were collected under two ambient light conditions, bright and dim. The dim-ambient-light condition was created by inserting a 2.7 OD neutral density filter in the optical pathway of the tracking device. The terrain luminance was measured with a Spectra Minispot Photometer. The average luminance at the objective of the lens of the tracking device was 250 lm/m^2sr with the filter removed and 0.8 lm/m^2sr with the filter in place. No light from the terrain entered the bunker except through the tracking device optics. During the bright-ambient-light condition the luminance inside the bunker was 5.0 lm/m^2sr. The bunker light was turned off during the low-light tracking condition. During the dim-ambient-light condition the volunteers sat in the darkened bunker for approximately 10 min to allow their eyes to adjust to the low-ambient-light level which approximated dawn/dusk. More complete descriptions of the BLASER system are included in reports by O'Mara et al (11) and Stamper et al (12).

Procedure. A brief question and answer period and the administration of the visual test battery were conducted at Ft. Ord. The participants were then assigned randomly in an exhaustive sequence (3/wk), to one of the three groups (N=8/group) in the order they arrived at the Presidio of San Francisco. To begin the study, each volunteer was seated in the bunker. Each tracking session started with the target on the left side of the terrain board. Each trial was initiated by the commands "READY", "GO". After each trial the volunteers were instructed to "RELAX" until the next "READY" command. Also they were given their summary statistics (percent time-on-target and standard deviation score) for that trial. All volunteers tracked in both directions (left-to-right and right-to-left).

Training. All groups received 4 days of training with the BLASER simulator. The first and second training days were the same for all groups. On these days all volunteers received a total of 54 tracking trials (Day 1: twenty-two 1-min trials; Day 2: thirty-two 15-sec trials) with their dominant (right) eye. Under this paradigm, all volunteers tracked the target for half the trials under the bright-ambient-light condition and half under the dim-ambient-light condition. All groups received 32 tracking trials of 15 sec each under the two light conditions on training days 3 and 4. The sequence of switching eyes and the direction of the target were varied according to the experimental design. The total training of Groups 2 and 3 was equivalent.

Group 1 (Control) Sighting with dominant (right) eye only; target moved left-to-right on odd trials and right-to-left on even trials.

Group 2 Sighting with right eye and then with left eye, alternating every 2 trials (a total of 8 trials per eye for each ambient light condition). Right eye tracked target moving left-to-right and returning right-to-left; then volunteer used left eye to track target in both directions.

Group 3 Sighting first with right eye then with left eye within each trial. Volunteer switched from sighting eye in response to auditory cue (clicking sound of Uniblitz shutter) 5 to 7 sec into each 15-sec trial. Target moved left-to-right during odd numbered trials and right-to-left during even numbered trials in both ambient light conditions.

Test Day. On the test day each volunteer was required to track under 2 lighting conditions (bright and dim light). The sessions were divided into 16 trials for each light condition. The volunteers were told that an unspecified number of flashes could occur at any time and were instructed to switch eyes when a flash occurred. Each volunteer was given a total of 4 flash trials during the experimental session (2 flash trials under each ambient light condition).

Test Scores, Statistical Design & Analysis. Each flash trial was divided into 3 periods based on a visual inspection of the time series plots of the aiming data. The first period was 2.5 sec before the flash and was designated as the sighting-dominant eye baseline. The middle period was 2.0 sec immediately after the flash and was labeled flash disruption interval. The third period, labeled the non-dominant eye baseline, was 2.5 sec after the flash disruption interval. An acquistion period and trial termination period accounted for the other 8 sec of the 15-sec period.

Horizontal and vertical RMS error scores were collected with the BLASER simulator. Horizontal root mean square (RMS) error scores were used in the Analysis of Variance (ANOVA) to evaluate the tracking period before and after the flash disruption periods. RMS scores were computed from the following equation:

$$\sqrt{\Sigma(X_i - XO)^2/N}$$

Where: X_i = location of the crosshairs

XO = central aiming point

N = number of sample points

Horizontal RMS error scores describe how well a tracker is able to keep the vertical crosshair of the reticle over the target patch. This task, in its present configuration, is composed mainly of a strong horizontal component. Therefore, only the horizontal RMS data will be presented. The vertical RMS data, as expected, were highly similar, but uniformly lower. (Additionally, while SD error scores were calculated and an ANOVA run on these scores, that data also will not be presented. The SD ANOVA results were identical to the RMS ANOVA results. The RMS scores yielded a higher value than SD error scores due to the use of a previously defined mean aiming point. The SD error scores were based on an operator-defined mean aiming point.)

Maximum error scores were also generated on-line by a point-by-point comparison of the data for each trial. The maximum error is a good indicator of the magnitude of the flash effect (13). These scores were converted to absolute values, averaged across subjects, and recovery curves plotted. The maximum absolute error scores reflect the largest excursion from the center of the aiming patch, without respect to the the direction of the excursion (lead vs lag).

The sighting-dominant eye baseline period was analyzed with a 3 (group) X 2 (light level) X 2 (direction) ANOVA. The flash disruption interval and non-sighting/non-dominant eye baseline were analyzed with a 3 (group) X 2 (light level) X 2 (flash order) X 2 (direction) ANOVA. The flash order factor was included to determine if performance was affected by the ambient light level where the tracker experienced his first flash. Order 1 was bright-ambient light trials followed by dim-ambient light trials (B/D) and Order 2 the opposite (D/B). The direction main effect refers to the direction the target was traveling (i.e. left-to-right or right-to-left).

The ANOVAs were performed with BMDP Statistical Software program 4V (14). This program includes a general purpose analysis of variance which provides both univariate and multivariate analyses, and includes repeated measures, split-plot, and changeover designs. In the present analyses group and order were treated as between-group factors. Light level and direction were treated as within-group fac s. The ANOVA treated the model as a factorial design with repeate. ıeasures. The 0.05 level was used for determining significance in all cases.

RESULTS

Sighting-Dominant Eye Baseline. The 3-way ANOVA performed on the horizontal RMS error scores to assess the effects of training on the sighting-dominant eye indicated that group and direction main effects were not significant, $F(2,21)=0.02$, $P>0.05$, and $F(1,21)=0.07$, $P>0.05$, respectively. As expected, due to the increased difficulty in tracking performance under the dim-ambient light condition, the light level main effect was significant $F(1,21)=18.77$, $P<0.001$. These results indicate that there were no significant differences among the groups at the end of the training period.

Effects of Training on the Flash Disruption Interval. Figures 1 and 2 depict the mean maximum horizontal error scores for the three groups under the bright and dim-ambient light conditions, respectively. Each figure presents the mean sighting-dominant eye baseline, flash disruption interval and non-sighting eye baseline periods for each group. During both baseline periods little differences were exhibited among the groups. However, during the flash disruption interval the data indicated some aspect of the training received by Group 3 significantly reduced the magnitude of the maximum excursion from the center of the target.

The 4-way ANOVA performed on the maximum absolute error scores to assess these effects confirmed the differences observed in Figures 1 and 2. The ANOVA revealed significant main effect for both group and light level, $F(2,18)=5.33$, $P<0.05$ and $F(1,18)=7.12$, $P<0.05$, respectively. No significant effects were found for the main effect of order and direction, $F(1,18)=2.42$, $P>0.05$, and $F(1,18)=2.82$, $P>0.05$, respectively, or any interaction containing order or direction.

Effects of Training on the Non-Sighting Eye Baseline. The 4-way ANOVA was performed on the horizontal RMS error scores to assess the effects of the training regimen on the non-sighting eye. The ANOVA revealed that the main effect for group was not significant $F(2,18)=1.36$, $P>0.05$. However, the main effect for direction nearly achieved significance, $F(1,18)=1.44$, $P=0.08$. Light level was significant, $F(1,18)=19.51$, $P<0.001$. Also, order was significant, $F(1,18)=5.03$, $P<0.05$. These results indicated that significant differences existed between trackers, depending on whether they experienced their first flash under the bright or dim ambient light condition.

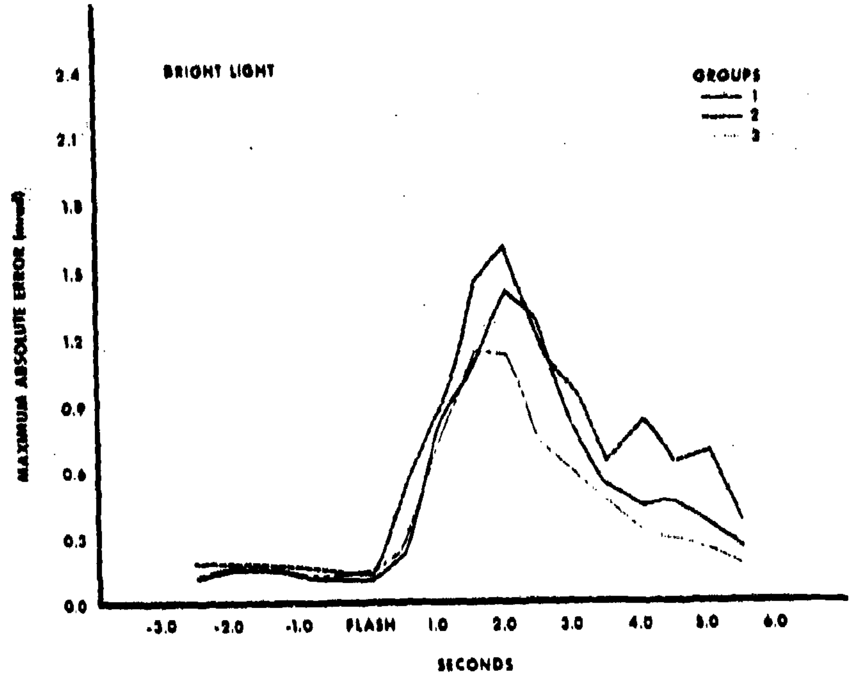

Figure 1. Maximum absolute error - Bright Ambient Light

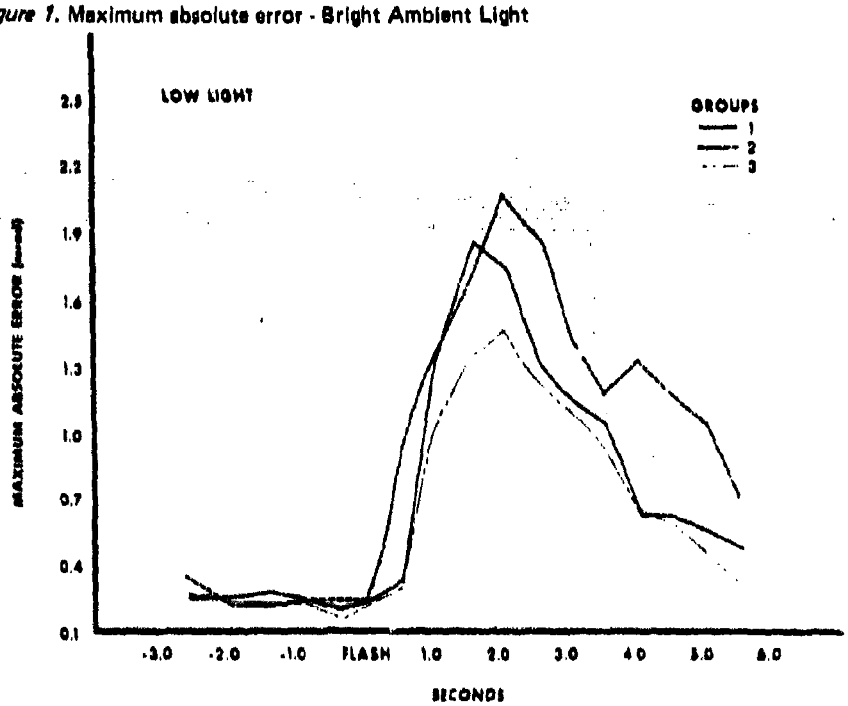

Figure 2. Maximum absolute error - Dim Ambient Light

DISCUSSION

A single full-field green strobe flash produced significant disruption of pursuit tracking performance under both bright and dim-ambient light conditions. The flash subtended approximately an 11^{o} field of view. During the flash disruption period when the target was completely obscured due to flash blindness, the trackers switched from the sighting-dominant eye to the non-dominant eye and resumed tracking. Under dim-ambient light conditions where the trackers were partially dark-adapted, horizontal MAE scores were significantly higher than during the bright-ambient light trials. RMS error scores under the dim-ambient-light condition were also higher than during the bright-ambient-light condition. Previous BLASER simulator studies (12,13,15) provided similar results with respect to light level and full-field flash.

The results of the ANOVAs performed on the dominant eye and non-dominant eye baselines showed that both group and direction were not significant. This indicated that during the dominant eye baseline the performance level before the flash disruption interval was the same for all groups. During the non-dominant eye baseline, this indicated that the groups had achieved approximately the same level of recovery at the end of each trial. However, the level of recovery was not equal to the dominant eye baseline performance level.

During the dominant-eye baseline period, target direction showed no statistical significance. However, during the non-dominant eye baseline we anticipated that target direction would be statistically significant. Our assumption was based on the head movements involved in eye-switching while performing pursuit tracking tasks. When the target moves to the right, body motion and eye-switching are rightward motions. Since the head motion "follows" the direction of travel and body motion, the eye-switching movement is smooth and easy for the right-eye dominant trackers. When the target moves to the left, body motion is the same; however, the eye-switching process invloves a rightward head motion to align the non-dominant eye with the ocular. The degree of difficulty may be higher for a target travelling to the left. For left-eye dominant trackers the leftward motion of the target and body would facilitate smoother eye-switching than the rightward motion of the target and body. Our data showed a probability of significance (P=0.08) but did not reach the level of confidence we set ($P \leq 0.05$).

This study utilized a full-field flash to elicit a startle response of a magnitude such that the operator reacted by pulling his head away from the eyepiece. This reaction facilitates eye switching. This flash was analagous to exposing the collecting aperture of the magnifying optics to a CO_2 laser. The subsequent reradiation and flash effects, except for the color of the flash, would be similar to the flash used in this study. Smaller flashes (100 micron retinal image), which would be received from fielded laser systems vary in energy density, pulse duration, and number of pulses. These factors may produce effects much more functionally disrupting than those produced by a broad-band source. If these factors did not produce as large a startle response as reported in this study, the operator may be able to retain visual contact with the target (13). The reduced startle response could, in turn, reduce error scores and decrease the maximum deviation when the operator switches eyes.

CONCLUSIONS AND RECOMMENDATIONS

Current training regimens do not, typically, specify eye choice. Configuration of the hardware may determine the eye the operator must use. Training operators of monocular optical devices to switch from the dominant eye to the non-dominant eye represents a possible solution to the immediate effects of flash exposure - flash blindness. With this training the operator would be able to complete the mission. These data suggest that if the flash occurred early in the tracking phase of a firing mission soldiers, after a short disruption period, would be able to re-acquire the target and hit the target if they were trained with this procedure.

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APPENDIX. Screening of Test Subjects

APPENDIX

SCREENING OF TEST SUBJECTS

To simplify the interpretation of the initial data, the following criteria must be met by each subject:

a. Corrected acuity of 20/20 or better in each eye tested at both near (30 cm) and distance (6m).

b. Normal color vision as manifested by a perfect score on the identification of symbols in the first 21 plates of the Ishihara Test for Color-Blindness (Kanchara Shuppan Co., Tokyo, Japan, 1969).

c. Dominance testing - Volunteers must be judged to right-eye dominant in accordance with the tests outlined below.

TESTS FOR OCULAR DOMINANCE

TEST I. THE CARD TEST

Three cards 7.6 cm x 23 cm. One is covered with black paper, one with blue, and one with green. In the center of the green card is a round red spot, on the black a gold spot and on the blue a red spot. The spots are the size of the end of an unsharpened pencil. Three other cards, of the same color, 6.0 cm x 17.5 cm, in the center of which there is a round hole of a size through which a round pencil may be inserted snugly.

Directions: The examiner takes the black card with the hole in the center and holds it momentarily about six or eight inches in front of his eyes and says at the same time, "I want you to hold this card in both hands and look through this hole." He then hands the card to the examinee. The examiner then picks up the black card with the gold spot and holds it in front of his face just below his eyes so that the spot is about even with his nose. The examiner then instructs the examinee to look at the spot first and then bring the card up in front of his face about six or eight inches in front of his eyes keeping both eyes open and look at the spot through the hole. Repeat with the remaining two cards. Record the sighting eye for each card. The score is not counted on the first card since it is used to get the examinee adjusted to the test.

TEST II. THE BOX TEST

A 5 x 7 x 12 cm box is made out of cardboard. The ends are left open. Through the shorter distance of one end was inserted a black pipe cleaner and through the other end a white pipe cleaner. This made the pipe cleaners 9.6 cm apart.

Directions: Hold the box about six or eight inches in front of your face using both hands without definitely aligning it with either eye. Tell the examinee to line up the black string with the white string keeping both eyes open. Record the sighting eye and repeat the test but turn the box aound so that the opposite string is facing the examinee.

TEST III. THE POINTING TEST

No equipment necessary.

Directions: The examinee should be seated approximately 3 feet in front of the examiner. Instruct the examinee to point a your nose. Record which eye the finger is aligned with. Repeat the above step, but have the examinee use the other hand. Repeat this twice so you have two scores for the right hand and two scores for the left hand.

Appendix (concluded)

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